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ASSEMBLY AND OPERATION OF THE DIRECT-
DRIVE PULSER

W. Wong, et al

Stanford Research Institute

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ASSEMBLY AND OPERATION OF DIRECT-DRIVE PULSER

W. Wong

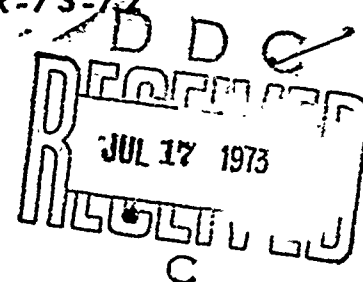
R. C. Adamo

R. T. Wolfram

Stanford Research Institute

TECHNICAL REPORT NO. AFWL-TR-73-72

June 1973



AIR FORCE WEAPONS LABORATORY

Air Force Systems Command

Kirtland Air Force Base

New Mexico

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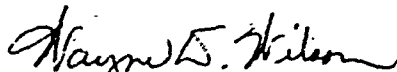
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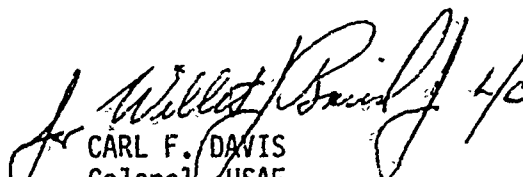
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Inclusive dates of research were August 1971 through February 1972. The report was submitted 21 March 1973 by the Air Force Weapons Laboratory Project Officer, Captain Wayne D. Wilson (ELE).

This technical report has been reviewed and is approved.


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ABSTRACT

(Distribution Limitation Statement A)

This report describes in detail the design, operation, and maintenance of a 12.5-kv direct-drive pulser used in the Minuteman In-Place Electromagnetic Pulse (EMP) Test Program. The pulser is intended to inject a pulse into electronic systems so that the effects of the transient pulse on the system under test can be determined. The detailed specifications of the pulser system are presented.

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I SPECIFICATIONS AND PRINCIPLES OF OPERATION

A. General Description

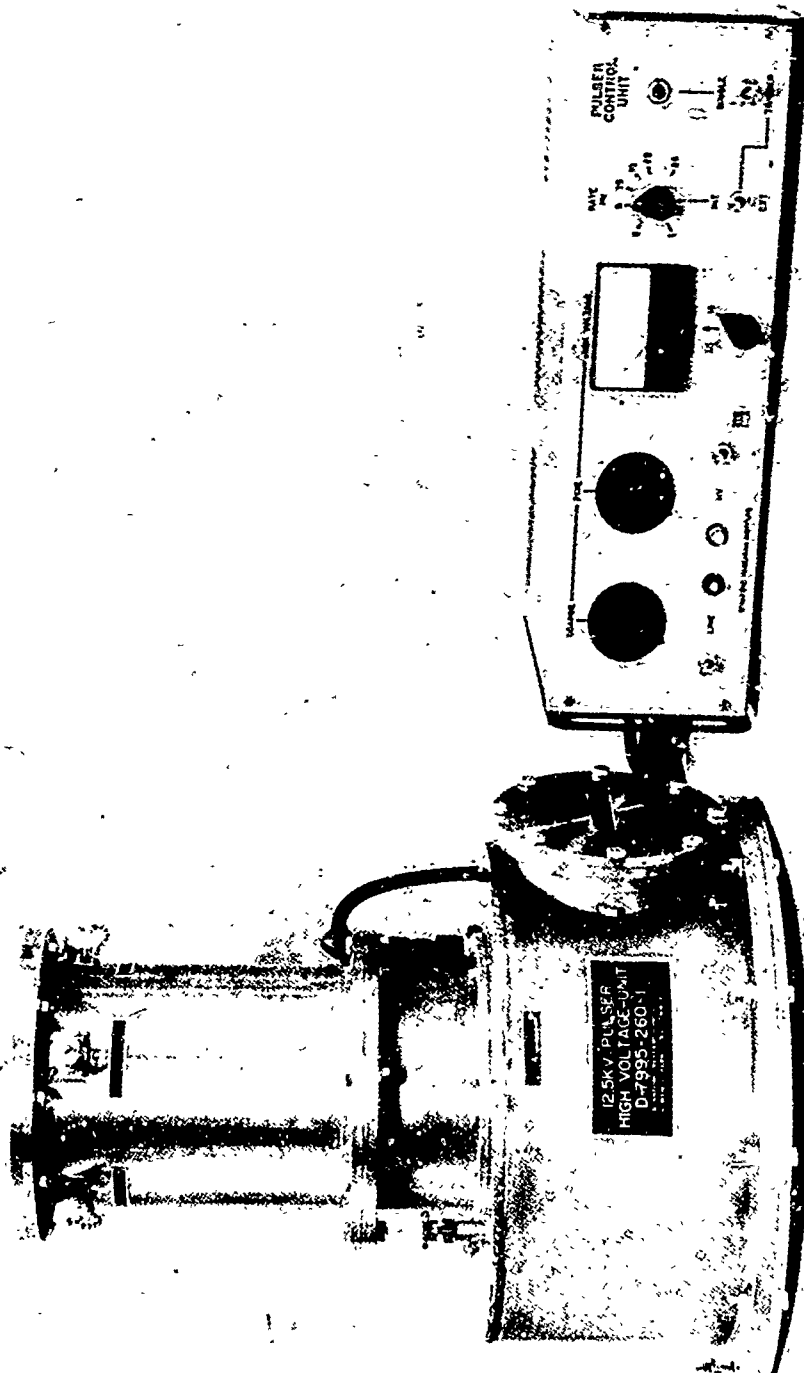
1. Pulser Unit

The Direct Drive Pulser was intended to inject its output pulses into electronic systems so that the effects of transients on the systems could be determined.

The Direct Drive Pulser, Figure 1, is comprised of two units-- a high-voltage pulser and a pulser control. The pulser unit consists of an energy-storage capacitor bank, an electromechanical switch, and a high-voltage dc power supply housed in an aluminum cylinder.

The energy-storage capacitor bank has a total capacitance of $0.01 \mu\text{F}$ with low inductance, consisting of five $0.002\text{-}\mu\text{F}$ capacitors connected in parallel. The capacitors are charged by a variable high-voltage dc power supply, 500 volts to 12.5 kilovolts, and then discharged into the output load by activation of a solenoid-driven switch. The switch can be actuated at variable repetition rates of 1 to 25 pps, or in a single-pulse mode. To maintain stability at high output voltages, greater than 10 kilovolts, it may be necessary to purge the pulser unit with a dielectric gas, such as sulphur hexafluoride (SF_6). Polarity reversal of the high-voltage power supply is possible to obtain negative or positive pulses.

The pulse unit has five output ports to provide a voltage to 1 to 5 loads simultaneously. In addition, a capacitive probe provides a trigger pulse that can be used to trigger oscilloscopes or other equipment. The output pulse shape is illustrated in Figure 2.



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FIGURE 1 HIGH-VOLTAGE PULSER AND PULSER CONTROL UNITS

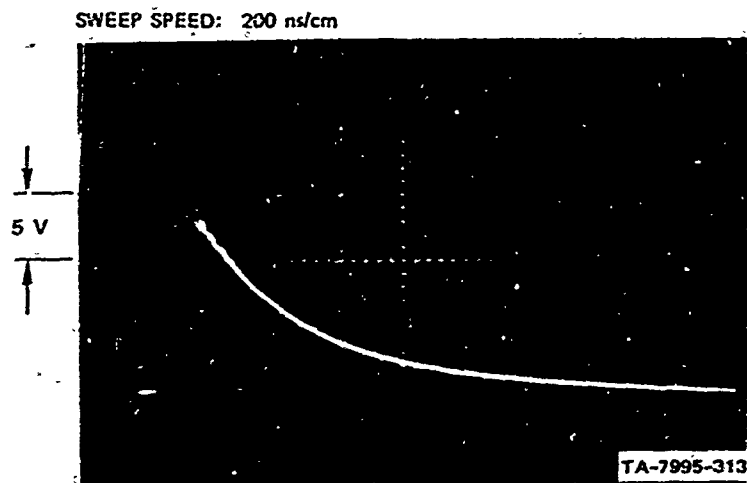


FIGURE 2 OUTPUT-PULSE SHAPE

2. Control Unit

The pulser control unit contains three sets of circuits--the pulser-switch drive and control, the high-voltage power-supply control, and the high-voltage voltmeter circuit.

The pulser-switch driver generates a variable bipolar drive pulse to close and relax the switch contact and also provide a small, fixed bias to hold the contact open between pulses. Repetitive pulses are generated by an internal trigger generator at a rate variable from 1 to 25 pps. The pulser can also be triggered by an external trigger pulse. Single pulses can be generated by a manually operated trigger switch on the control front panel.

Two variacs are provided for fine and coarse control of ac power to the high-voltage dc power supply in the pulser unit. An electronic voltmeter monitoring the high-voltage power-supply output is provided in three ranges--1.5, 5, and 15 kV, full scale.

An interconnecting and wiring diagram of the pulser and control units is given in Figure 3.



FIGURE 3 INTERCONNECTING-WIRE DIAGRAM

NOTES:

- 1) All capacitors are in μF unless noted.
2) All resistors are $\text{k}\Omega$ and are in ohms unless noted.

B. Specifications

Specifications of the direct-drive pulser are as follows:

- Output pulse Double exponential.
- Pulse rise time < 10 ns.
- Pulse-decay time constant 0.5 μ s.
(with 50 ohm load)
- Peak output voltage Variable, 500 V to 15 kV.
- Repetition rate Variable, 1 to 25 pps single pulse with manual control. External trigger input provided.
- External-trigger input 2 V, positive pulse, 10 V maximum.
Input impedance 2 k Ω
- Scope-trigger output Plate antenna providing 8 V peak per kV into a 50- Ω output receptacle. Source capacitance of the voltage monitor is 1000 pF.
- Output cables RG-8A/U.
- Gas dielectric Sulphur hexafluoride, SF₆ (for operation above 10 kV only).
- Primary power requirements 105 to 125 Vac, 60 cycles, 1 phase, 120 watts.
- Dimensions and weights Pulser unit: outside diameter 16 inches, height 20 inches, weight 46 pounds.

Pulser control unit: width 17 inches, height 6 inches, depth 12 inches, weight 18 pounds.

C. Performance

Laboratory tests performed provided a typical output-pulse shape across a 50- Ω load, with the pulser operating at 15 kV in the single-pulse mode, SF₆ purged, as shown in Figure 2.

D. Operation

CAUTION: HIGH VOLTAGE. Safety precautions must be observed while operating the Direct Drive Pulser.

To avoid shock hazard, connect a lead from a good ground to the pulser-unit base.

Alternating-current power must be off and capacitors discharged before any attempt is made to service the high-voltage unit or to reverse polarity in the high-voltage dc power-supply assembly.

1. Front-Panel Controls (Figure 4)

The following controls are found on the front of the control unit:

- (1) LINE--This switch controls the main ac power input to the Pulser Control Unit. The adjacent pilot indicates power ON.
- (2) HV--This switch controls the ac power input to the control variacs for the HV power supply. The adjacent pilot indicates HV ON.
- (3) FINE, COARSE--These controls adjust the ac input voltage to the HV power supply.
- (4) RANGE-HV--This switch selects the range of the high-voltage voltmeter. In each position, the numerals indicate the full-scale voltage reading.

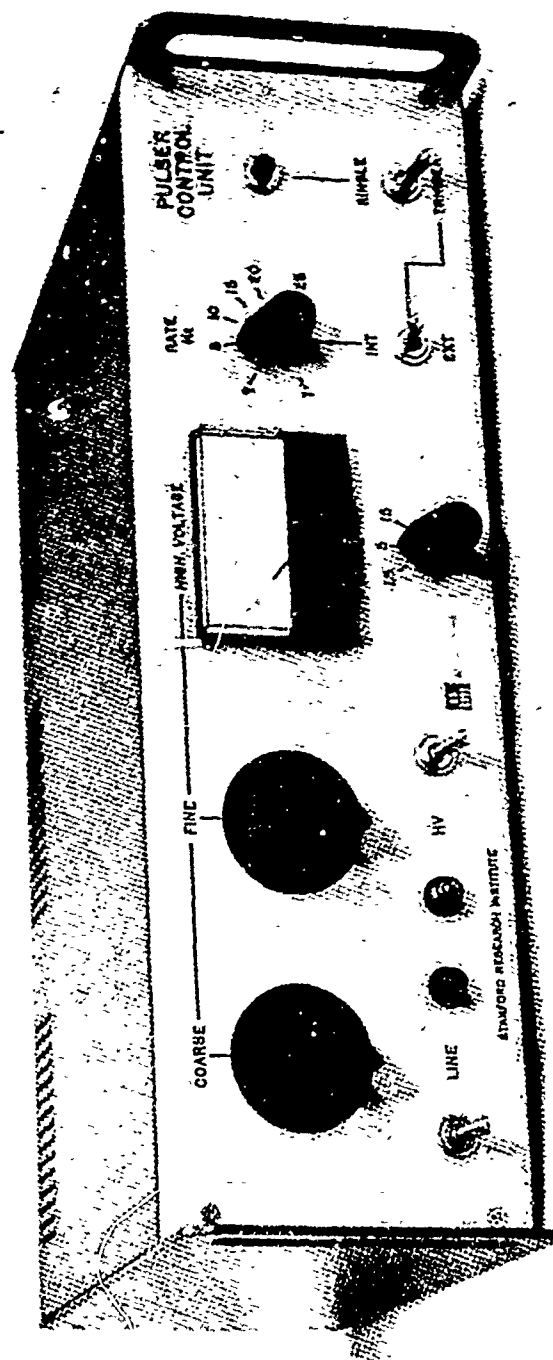


FIGURE 4 PULSER CONTROL UNIT, FRONT-PANEL CONTROLS

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- (5) SINGLE/TRIGGER--This switch selects the operating mode of the drive-pulse generator.
- (a) SINGLE--In this position, one drive pulse is generated each time the SINGLE button (directly above the switch) is pushed.
 - (b) TRIGGER--In this position the drive-pulse-generator input mode is transferred to the INT-EXT switch.
- (6) INT-EXT--This switch selects the trigger source for the pulse generator.
- (a) INT (Internal)--In this position, the generator is triggered by the internal trigger source.
 - (b) EXT (External)--In this position, the generator can be triggered by an external 10-V positive trigger pulse applied to the EXT TRIG receptacle on the rear panel (see Figure 5). Input impedance is 2 k Ω .
- (7) RATE--This control sets the trigger rate in the internal trigger mode. The rate is adjustable from 1 to 25 Hz.

The meter-polarity switch is on the rear panel. It is used to reverse the connections to the voltmeter if it is desired to operate the system with the high-voltage power supply connected for a negative output pulse.

2. High-Voltage-Unit Polarity and Purging

Access into the high-voltage dc power-supply assembly to reverse polarity is provided through the side porthole. Reversing polarity is accomplished by switching the red (+) and black (-) pin plugs.

The pulser unit is not designed for pressurization. Purging sulphur hexafluoride (SF_6) into the pulser unit is necessary when voltage levels exceed 10 kV. Connect Poly-Flo tubing to purge valve and remove an output connector dust cap or output cable to bleed through gas. To operate at levels below 4 kV, it will be necessary to remove the SF_6 by purging the pulser with clean air or dry nitrogen.



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FIGURE 5 PULSER CONTROL UNIT, REAR-PANEL CONTROLS

II PULSER UNIT

A. Energy-Storage Capacitor Bank

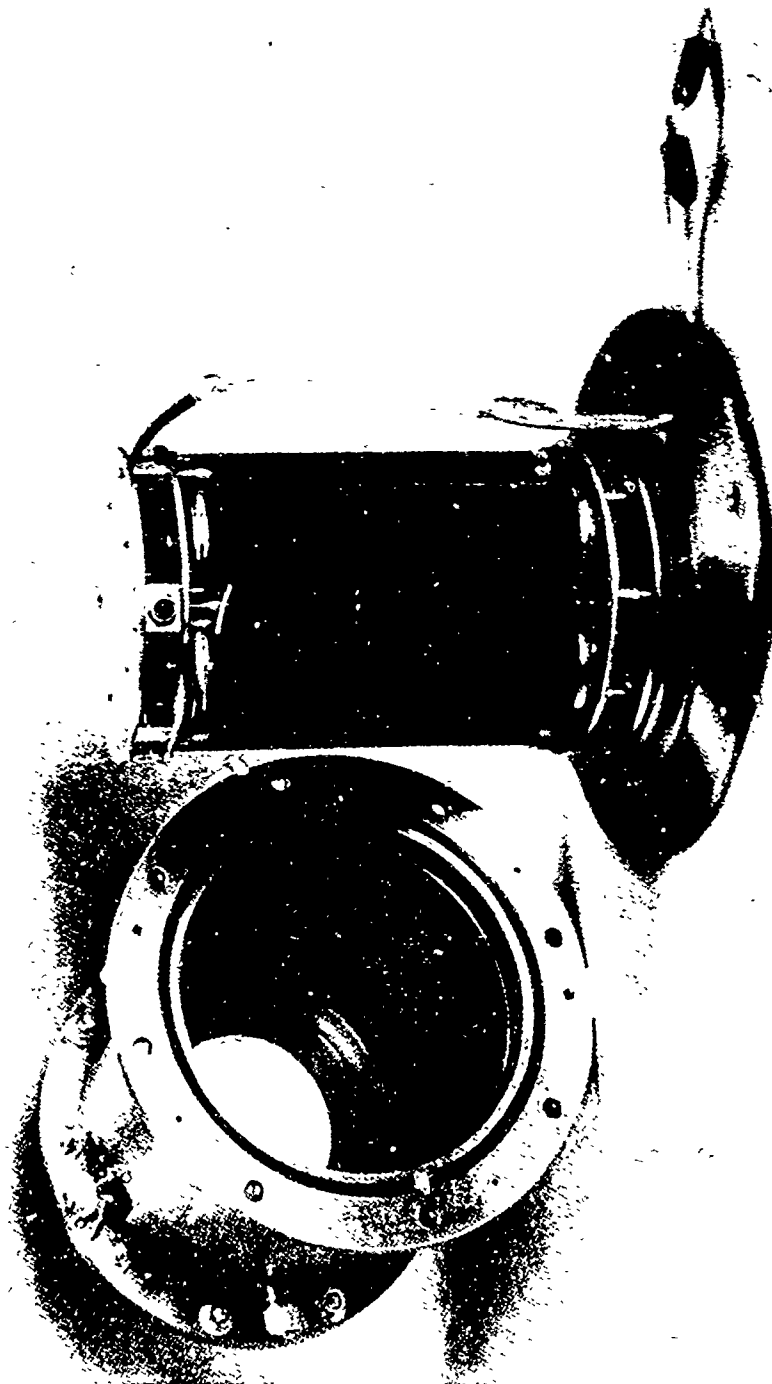
The individual capacitors are contained in hard glass shells, impregnated with oil, and hermetically sealed with metal ferrules soldered to each end. The end ferrules and the capacitors are fragile and cannot be subjected to extreme tightening, twisting, or shock. Such treatment may cause oil leaks, cracked shells, or other damage to the capacitors. Extreme care must be exercised while removing the capacitor bank as a unit or the capacitors individually.

The energy-storage capacitor bank has a total capacitance of $0.01 \mu\text{F}$, which consists of five $0.002\text{-}\mu\text{F}$, 20-kVdc capacitors connected in parallel. The capacitors are supported between two parallel end plates spaced apart and held together by 5 Lexan rod spacers. Special bushings, springs, and metal-mesh washers are used for cushioning the capacitors and making positive contact with the end plates (see Figures 6 and 7). On the top end plate of the bank are five output jacks and a series string of 10 resistors, totaling $1.5 \text{ k}\Omega$, connected between the capacitor terminals and ground (chassis). The $1.5\text{-k}\Omega$ resistor is a part of the dc charging circuit for the capacitors. At the bottom end of the bank end plate is the adjustable spark-gap electrode and another series string of resistors at $1.5 \text{ k}\Omega$. The assembled capacitor bank is held in the housing by two polystyrene spacers along with the appropriate O-rings. The resistor leads are fed through the bottom housing plate and are connected to the black and red pin jacks in the switch compartment. When disassembling and reassembling the capacitor bank, note the positions of the two



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FIGURE 6 CAPACITOR-BANK ASSEMBLY REMOVED FROM PULSER UNIT



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FIGURE 7 CAPACITOR BANK REMOVED FROM ASSEMBLY HOUSING

resistor leads fed through the bottom plate, the alignment of the five output jacks with the housing output connectors, and the position of the spark-gap center electrode.

Figures 6 and 7 illustrate the capacitor bank removed from the pulser unit, with the capacitor bank assembled in and out of the housing. In Figure 7, note the plate antenna on the underside of the top of the housing.

B. Switch

The switch is housed in the center compartment of the pulser unit. The switch is a solenoid-displaced-diaphragm unit actuated by pulses from the trigger generator in the pulser control unit. The trigger generator provides variable repetition rates of 1 to 25 pps or a single pulse operated by a manual switch on the control unit. An external trigger of 2 V, positive-pulse, not to exceed the 1-to-25-pps rate, through the control-unit trigger generator can also be used to actuate the switching mechanism.

The switching mechanism consists of an iron housing, permanent-magnet pole piece, a special formed coil with polyurethane pad, and a beryllium-copper contact plate. The switching mechanism can be removed for service by removing four socket cap screws. It is anticipated the switch contact plate will be most often replaced after a period in operation. This is accomplished by removing the polyurethane foam pad and contact plate and cementing in the new replacement unit.

The coil replacement is accomplished by removal of the screws on the bottom of the iron housing, after the coil leads have been disconnected, and then simultaneously removing the coil and housing. The coil dimensions are critical because of the tolerances necessary for the solenoid displacement action.

The switch discharges the charged capacitor bank upon receiving a trigger pulse from the control unit. At lower voltages the switch discharges the bank when the diaphragm contacts the spark-gap electrode, and at high voltages when the diaphragm is close enough for the gap to arc over.

Figure 8 illustrates the solenoid-operated switch in its compartment with the energy-storage-capacitor housing assembly removed. Note the acrylic stand-off plate with the pin jacks for connecting the capacitor bank to the high-voltage power supply and to ground. It is not necessary to remove the stand-off plate to service the switching mechanism.

The switch housing has dowel pins for alignment of the capacitor bank and high-voltage assemblies. Installation of the switch-housing bolts in the high-voltage-assembly housing will require a sealant compound on the bolt threads. Loctite Sealant, Grade C, Catalog #84-21, and Locquic Primer, Grade T, are recommended for this purpose.

C. High-Voltage dc Power Supply

The high-voltage dc power supply, shown in Figure 9, is contained in the base assembly of the pulser unit. The power supply is a 15-kV, 5-mA supply and can be energized only by the line and HV switches on the pulser control unit. Variable high-voltage levels are adjusted by the two variacs, coarse and fine, on the control unit.

The high-voltage-power-supply assembly consists of a 15-kV power pack, an 800-k Ω current-limiting resistor in series with the capacitor bank, and a 150-M Ω multiplier resistor for the electronic voltmeter circuit. A neon-light clamping circuit is installed at the low-voltage end of the 150-M Ω metering resistor as a safety precaution in the event of a malfunction or disconnection in the voltmeter circuit.

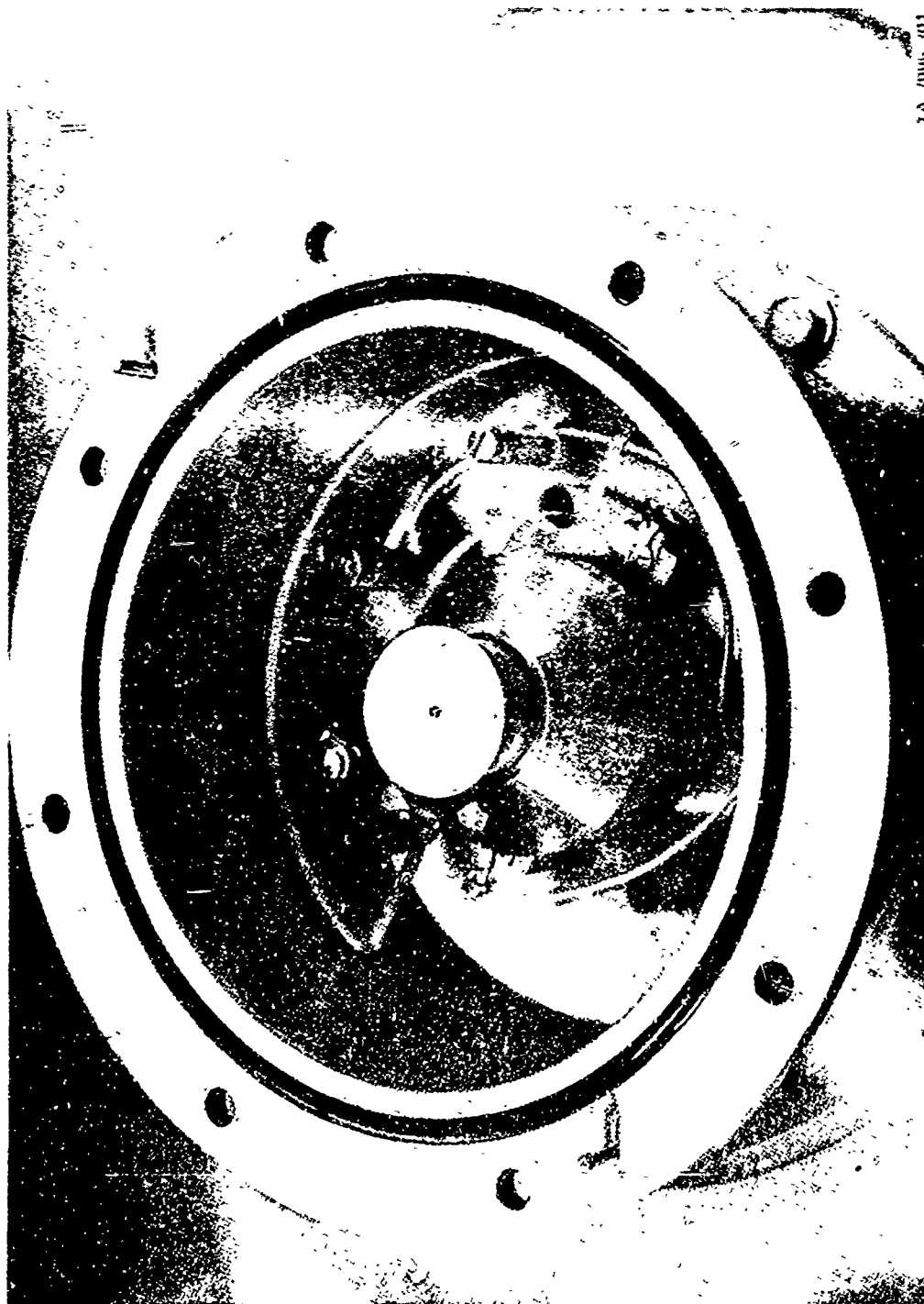
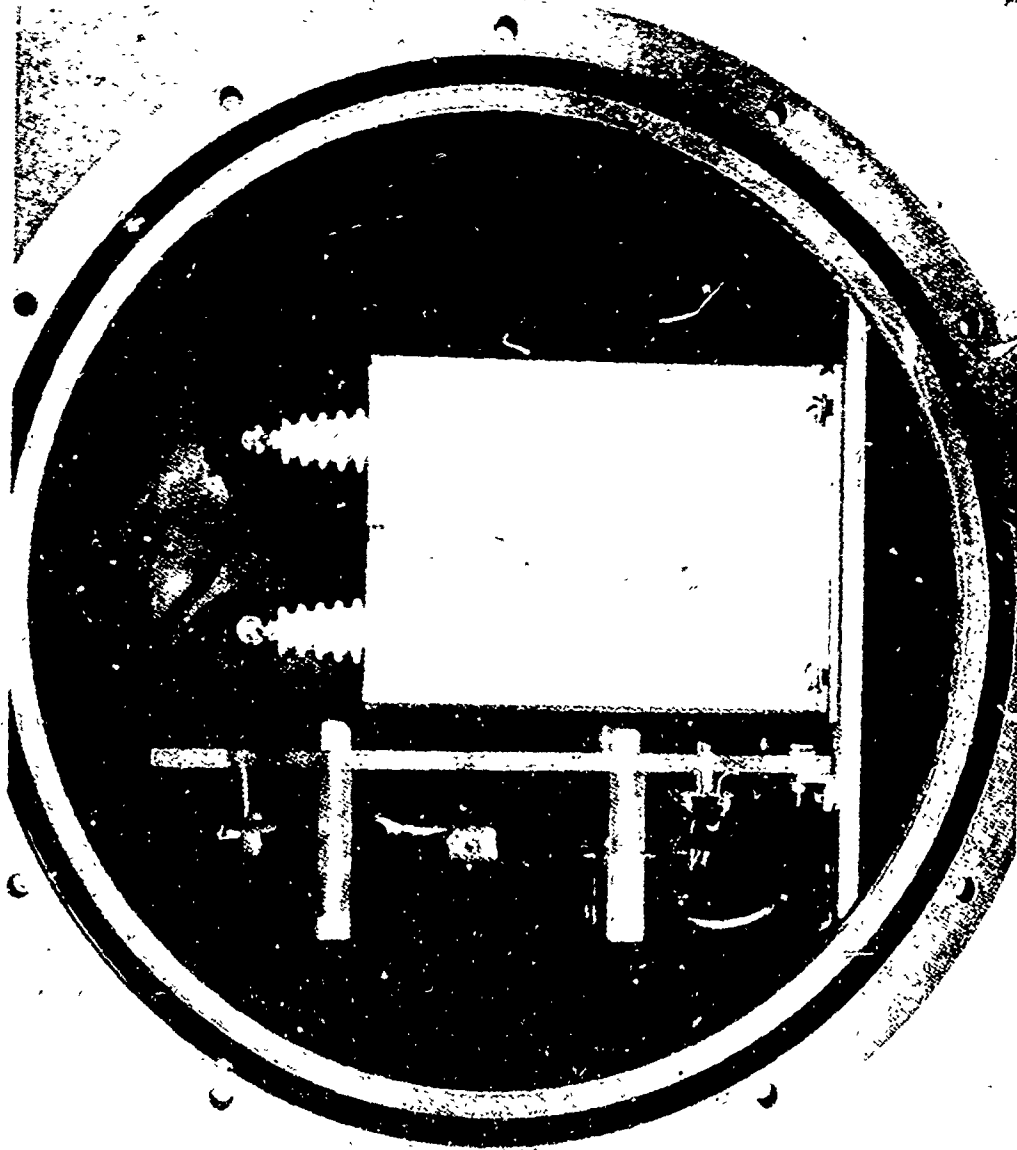


FIGURE 8 SOLENOID DISPLACEMENT DIAPHRAGM SWITCH



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FIGURE 9 HIGH-VOLTAGE POWER-SUPPLY ASSEMBLY

The power pack is installed in a horizontal position and secured by four screws along with special shims under the mounting brackets. Voltage outputs and polarity are identified by the pin jacks and plugs, red (+) and black (-) as illustrated in Figure 10. Changing polarity of the power-supply output is accomplished by reversing the respective pin plugs. Access to these may be accomplished by removing the access-port plate on the side of the pulser-unit base assembly.

The 800-k Ω current-limiting and 150-M Ω voltmeter multiplier resistor, which are both bracket-mounted with nylon screws, along with the meter-clamping circuit, are all mounted on the acrylic divider next to the power pack. The 150-M Ω resistor is encased in an acrylic tube with some non-corrosive RTV, Dow Corning 3145, to prevent damage to the resistor. Removal of the resistors requires unscrewing the nylon screws in the bracket and removing the appropriate wire connections. Replacing the resistors requires careful positioning, to prevent the resistor ends from being too close and arcing over to the assembly wall.

The panel-mount connector MS3102E-20-7P on the pulser-unit base assembly is provided for the connecting cable to the pulser control unit. The connecting cable, Belden 8418, is shielded and has eight conductors.

The purge valve, also located on top of pulser base assembly, is the input for the gas dielectric into the pulser unit. The valve is an Imperial-Eastman #312C, angle type, 1/8-inch male pipe thread to 1/4-inch Poly-Flo tubing. Purging of the pulser unit is done with the gas sulphur hexafluoride (SF_6). Gas flow-through is accomplished by removing the dust cap from one unused output connector or by removing and reinserting an output cable.

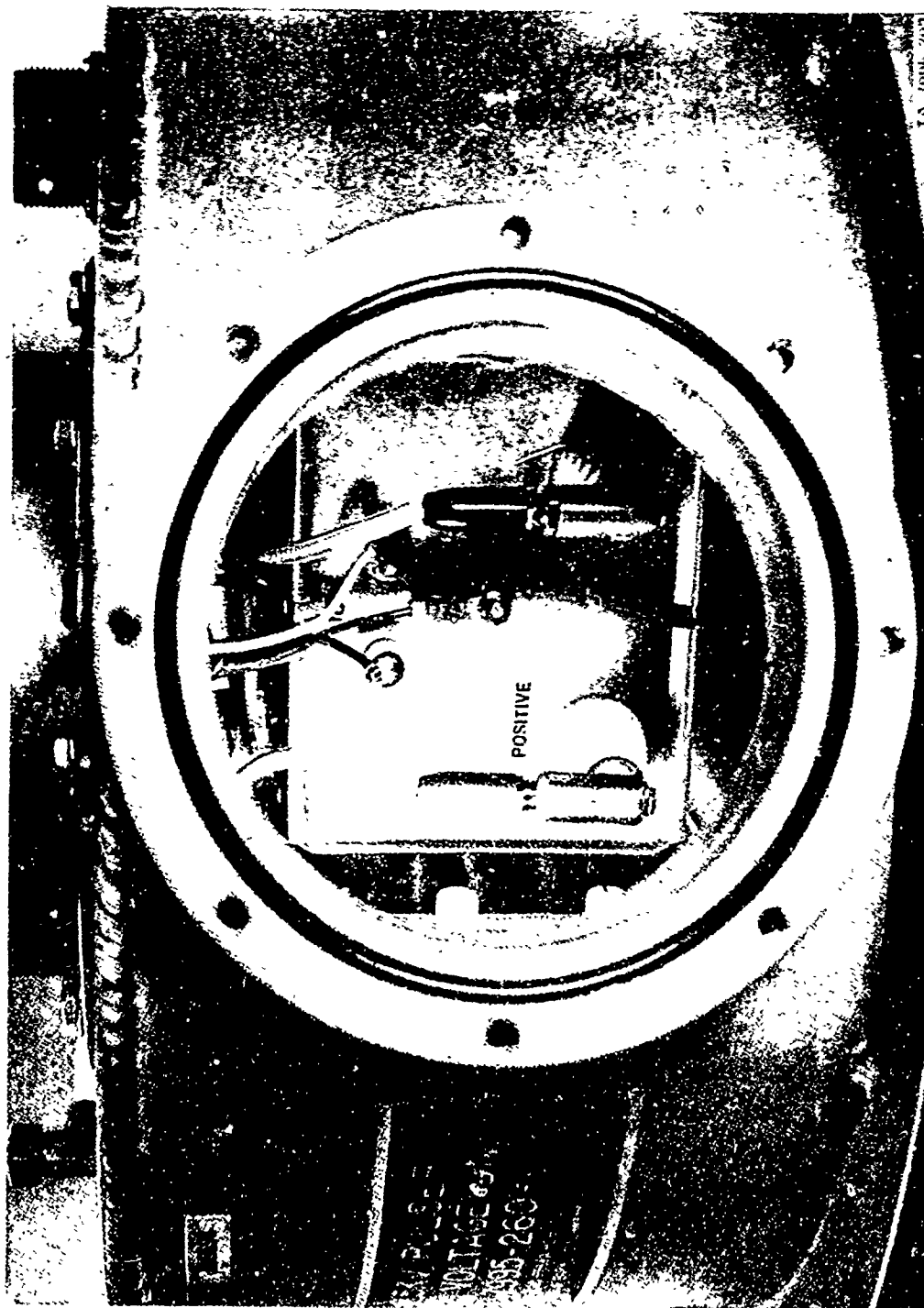


FIGURE 10 ACCESS PORT, POLARITY REVERSAL

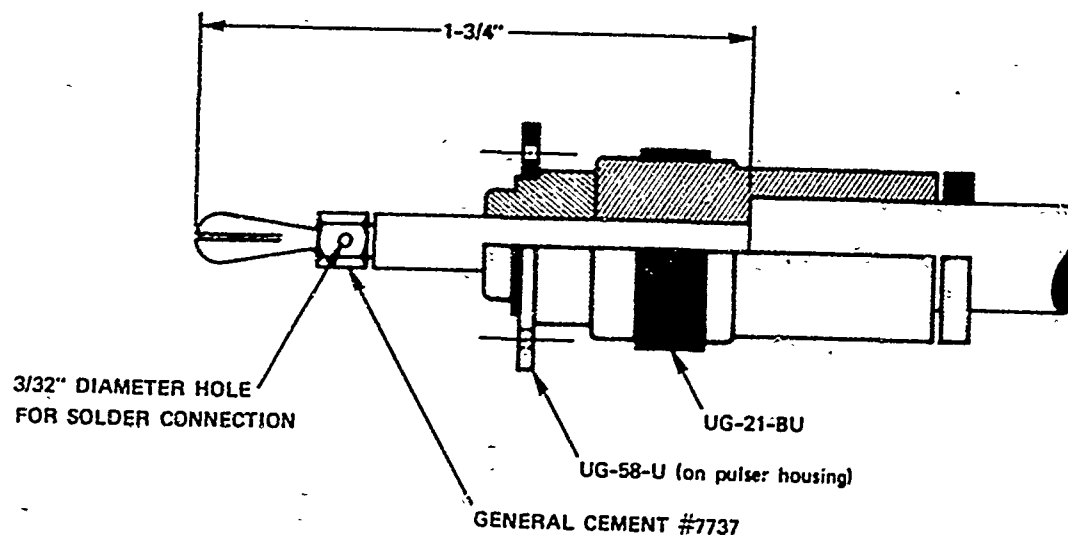
D. Plate Antenna

The plate antenna, built into the capacitor-bank housing, is located atop the pulser unit. It provides a triggering pulse and also is used to monitor the output pulse to the pulser output cables. The plate-antenna output is an N-type connector, 50 Ω , providing a pulse of 8 volts per kilovolt (peak). The source capacitance of the plate antenna is 1000 pF. Figure 6 shows a portion of the plate antenna inside the capacitor housing.

E. Output Cables

The pulser unit has provisions for up to five output cables. Any number of these may be used simultaneously. The output connectors are UG-58A/U jacks modified to accommodate the polyethylene insulation and center conductor of an RG-8A/U coaxial cable with a modified UG-21B/U connector. The load end of the cable can be fitted with an alligator clip or battery test clip with the copper shield removed for at least 2 inches from the end to prevent arcing from center conductor to shield.

The output connectors are capped with a dust cap MX-913/U and should remain covered when the output connectors are not in use. Care must be exercised, while inserting output cables into the pulser, to prevent shifting the capacitor bank or damaging the capacitors by applying excessive force. Figure 11 illustrates the fabrication and assembly of the output cable. An assembly drawing for the pulse high-voltage unit is shown in Figure 12.



NOTE: 0.281 diameter drill through UG-58-U and UG-21-BU.

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FIGURE 11 FABRICATION AND ASSEMBLY OF OUTPUT CABLE

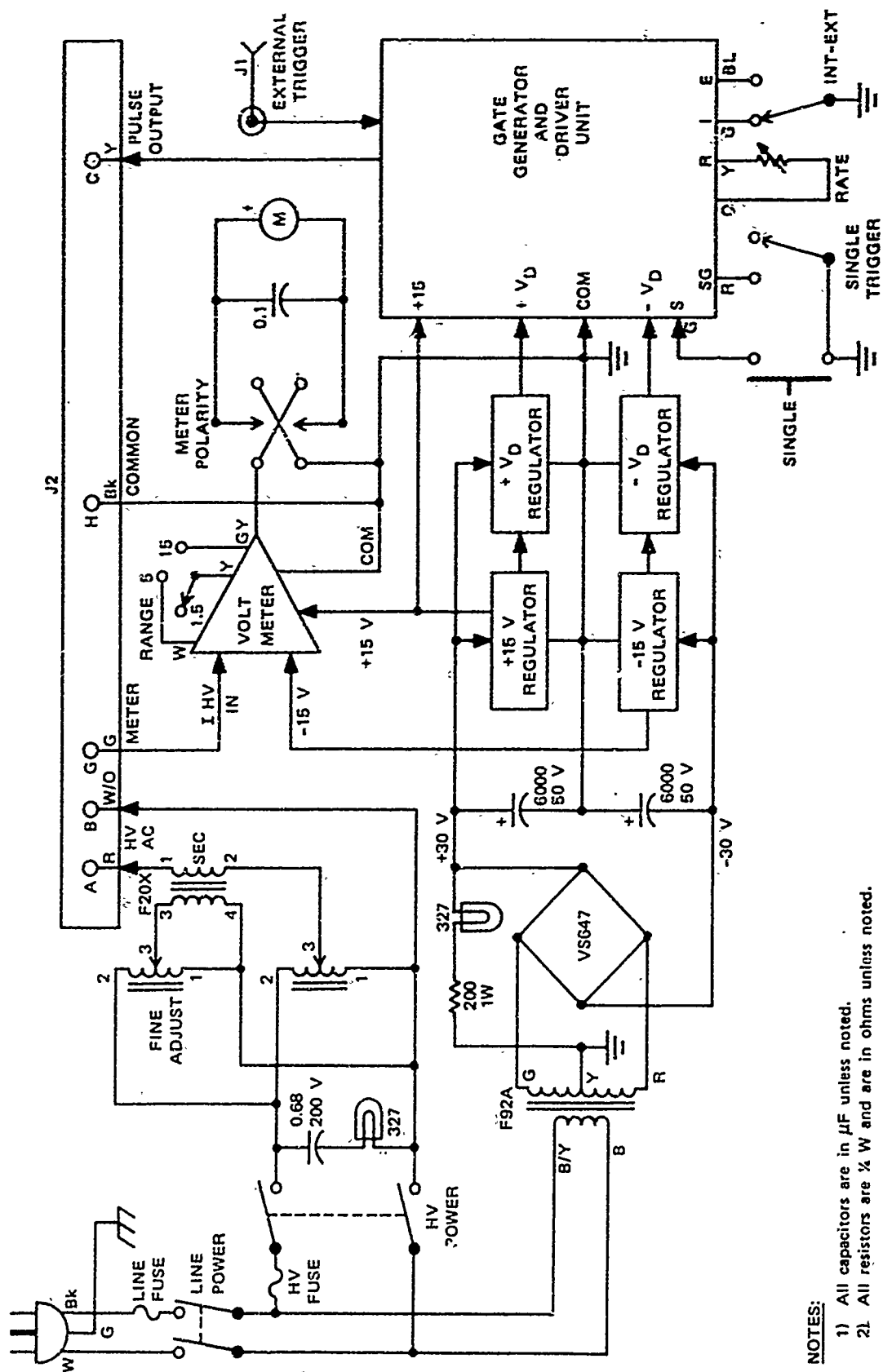
Figure 12 is a fold-out and will be found at the back of this report.

III PULSER CONTROL UNIT

A. General Description

The Pulser Control Unit contains three sets of circuitry--the pulser high-voltage switch drive and control circuitry, the high-voltage power-supply control circuitry, and the voltmeter circuitry. Direct-current power supplies are also provided. A partial schematic diagram of the control unit is shown in Figure 13.

The pulser-driver circuitry generates a variable-rate bipolar drive pulse for the pulser high-voltage switch. The drive-pulse waveform is shown in Figure 14. The positive portion of the waveform closes the contacts and the negative portion pulls them open. A small, fixed, negative bias holds the contacts open between pulses. Repetitive pulses can be generated by an external trigger, or the internal 1-to-25-Hz trigger generator. Single pulses can be generated by a manually operated trigger switch. The amplitude and duration of the positive and negative portions of the output drive pulse have been made adjustable by internal controls for optimum HV-switch operation. Two Variacs are provided for fine and coarse control of the ac-line power to the high-voltage power supply in the pulser HV-switch assembly. An electronic voltmeter is provided for monitoring the high-voltage power-supply output. Three ranges--1.5, 5, and 15 kV full scale--are provided.

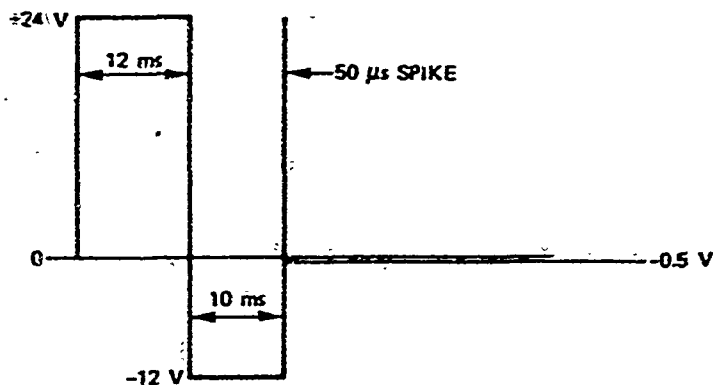


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FIGURE 13 PULSER-CONTROL-UNIT WIRING DIAGRAM

NOTES:

- 1) All capacitors are in μF unless noted.
- 2) All resistors are $\frac{1}{4}$ W and are in ohms unless noted.



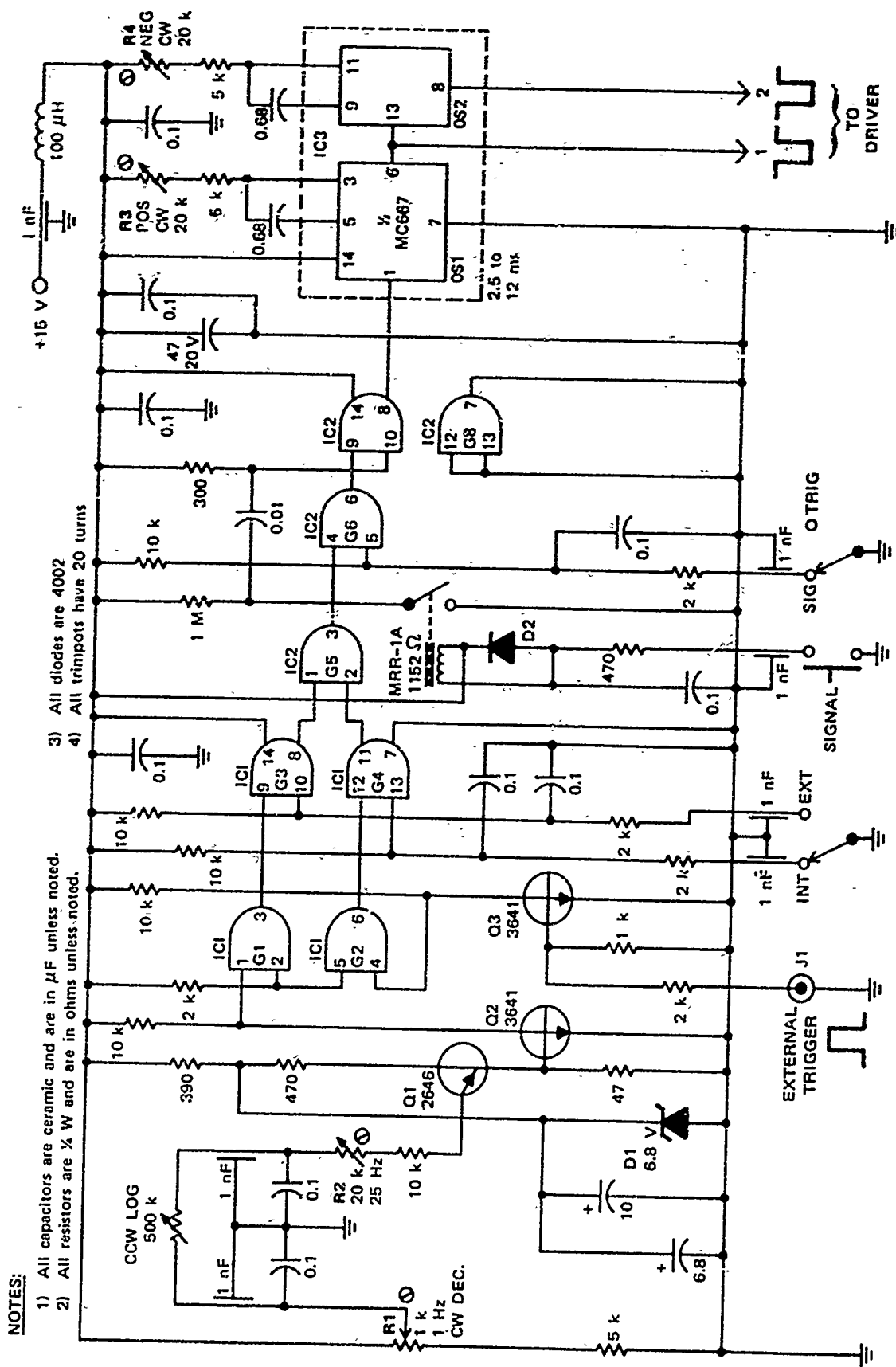
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FIGURE 14 DRIVE-PULSE WAVEFORM

B. Basic Circuit Operation

1. Pulse-Drive Circuitry

The drive-pulse gate-generator schematic diagram is shown in Figure 15. A unijunction oscillator, Q1, generates a variable rate pulse for internal triggering. Q2 inverts and amplifies the unijunction output pulse. Q3 inverts and amplifies the external trigger pulse from J. The mode-selection and control circuitry utilizes MHTL high-level logic NAND gates for maximum noise immunity. G1 and G2 act as inverter-drivers for the two trigger-source select gates, G3 and G4. The INT-EXT switch activates the corresponding gate. G5 acts as a NOR gate to invert the trigger-pulse signal from G3 or G4. The G5 output drives the mode-control gate, G6. This gate is activated by the SINGLE/TRIGGER mode switch in the TRIGGER position, and inverts the trigger pulse. The single-shot trigger is generated by a relay-operated RC pulse circuit. The relay is energized by the SINGLE pushbutton switch. G7 acts as a NOR gate to invert the trigger-pulse signals from G6 or the single-shot circuit. The output of G7 drives a one-shot gate generator OS-1. This one-shot generates a drive-gate signal for the positive portion of the HV-switch drive signal. This gate signal also triggers a second one-shot, OS-2, which generates the gate for the negative portion of the relay



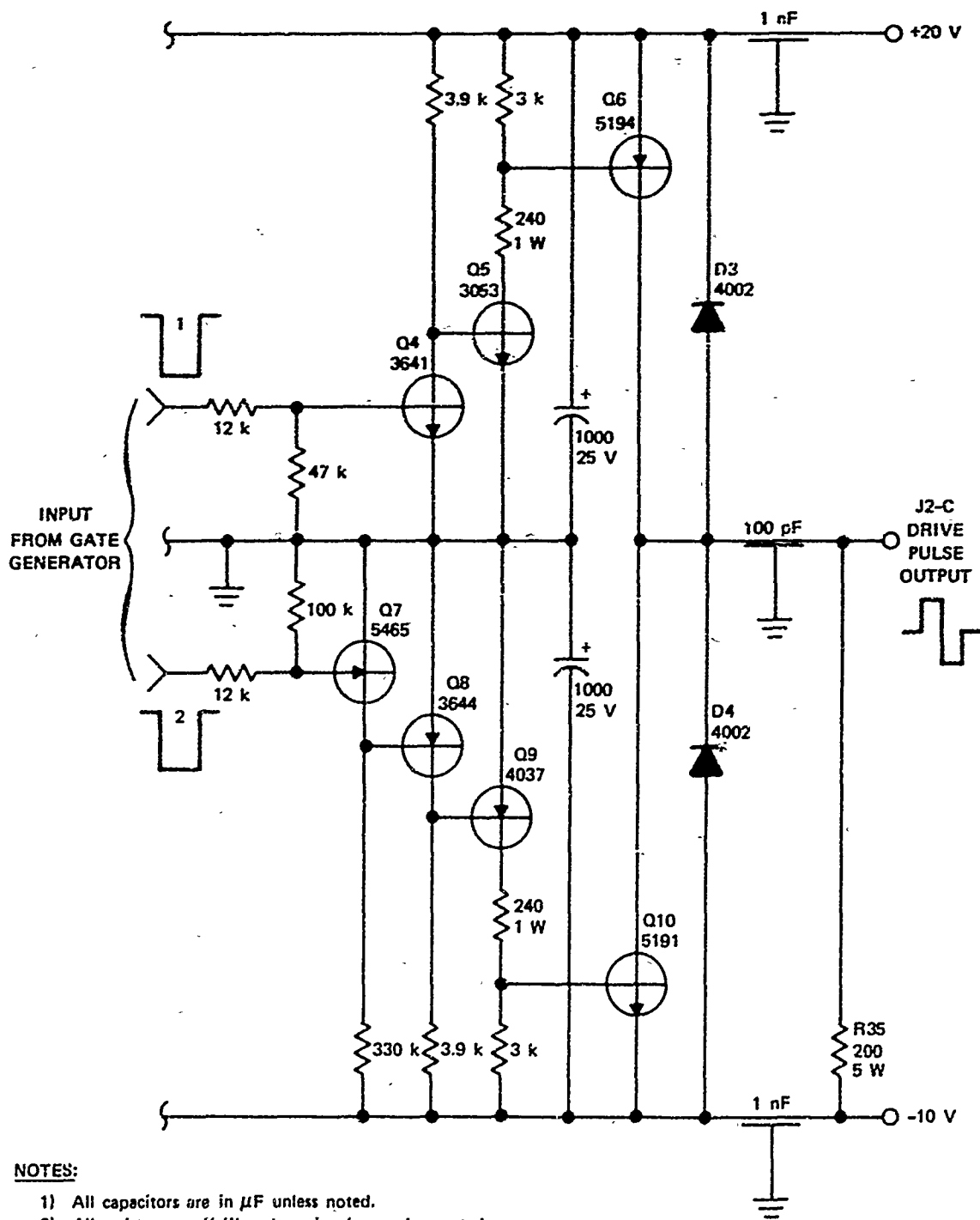
drive signal. The two drive-gate signals are fed to the pulser HV-switch driver circuitry shown in Figure 16. This circuit is a symmetrical bipolar power driver using complementary transistors. The gate input pulse is high between pulses. This keeps Q4 in conduction and its low V_c holds off Q5 and the positive-swing output transistor, Q6. When the input gate goes low, Q4 is cut off and Q5 conducts and drives Q6 to saturation. This switches the pulser HV switch coil to the positive driver supply voltage, $+V_D$. The negative drive circuitry operates in a similar manner except that an additional transistor, Q7, is used as a translator-inverter to convert the positive-input gate signal to a negative drive signal for Q8. R35, connected from the output terminal to $-V_D$, supplies a fixed negative bias current to the HV switch coil to hold it in the down, or off, position between drive pulses.

2. Voltmeter

A schematic diagram for the electronic voltmeter is shown in Figure 17. An operational amplifier, IC3, is used as a current amplifier to convert the low value of monitor current from the HV power supply to a 5-mA drive for the panel meter. Three voltage ranges are obtained by switching resistor values in the operational-amplifier feedback network. Equal full-scale output voltages are thus obtained for three different input currents, corresponding to 1.5, 5, and 15 kV at the HV power supply.

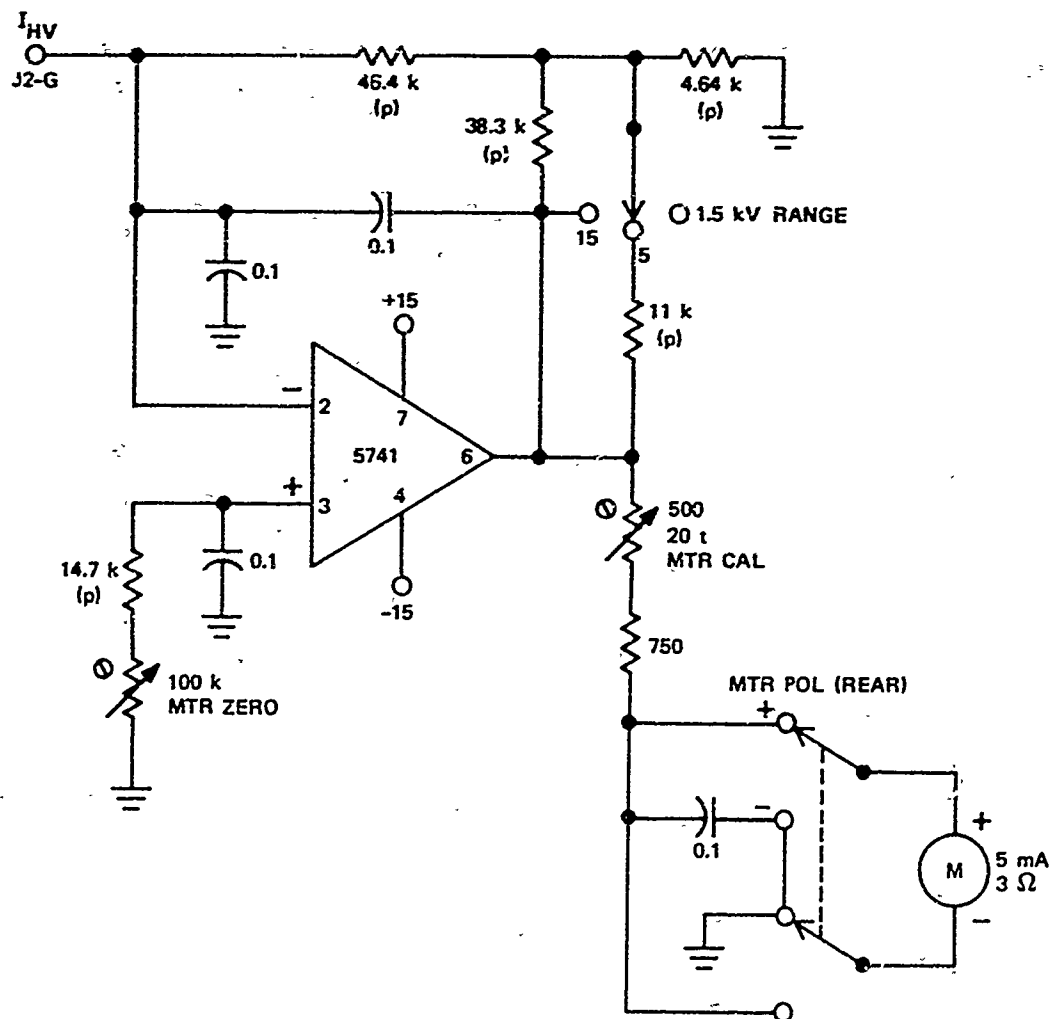
3. Power Supplies

Positive and negative 30 V for operation of the power supply regulators is supplied by the bridge rectifier circuit shown in Figure 13. Positive and negative 15 V is supplied by the tracking dual regulator shown in Figure 18. IC regulator units are used with external series pass transistors and protective diodes. The variable positive and



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FIGURE 16 PULSER-HV-SWITCH DRIVER

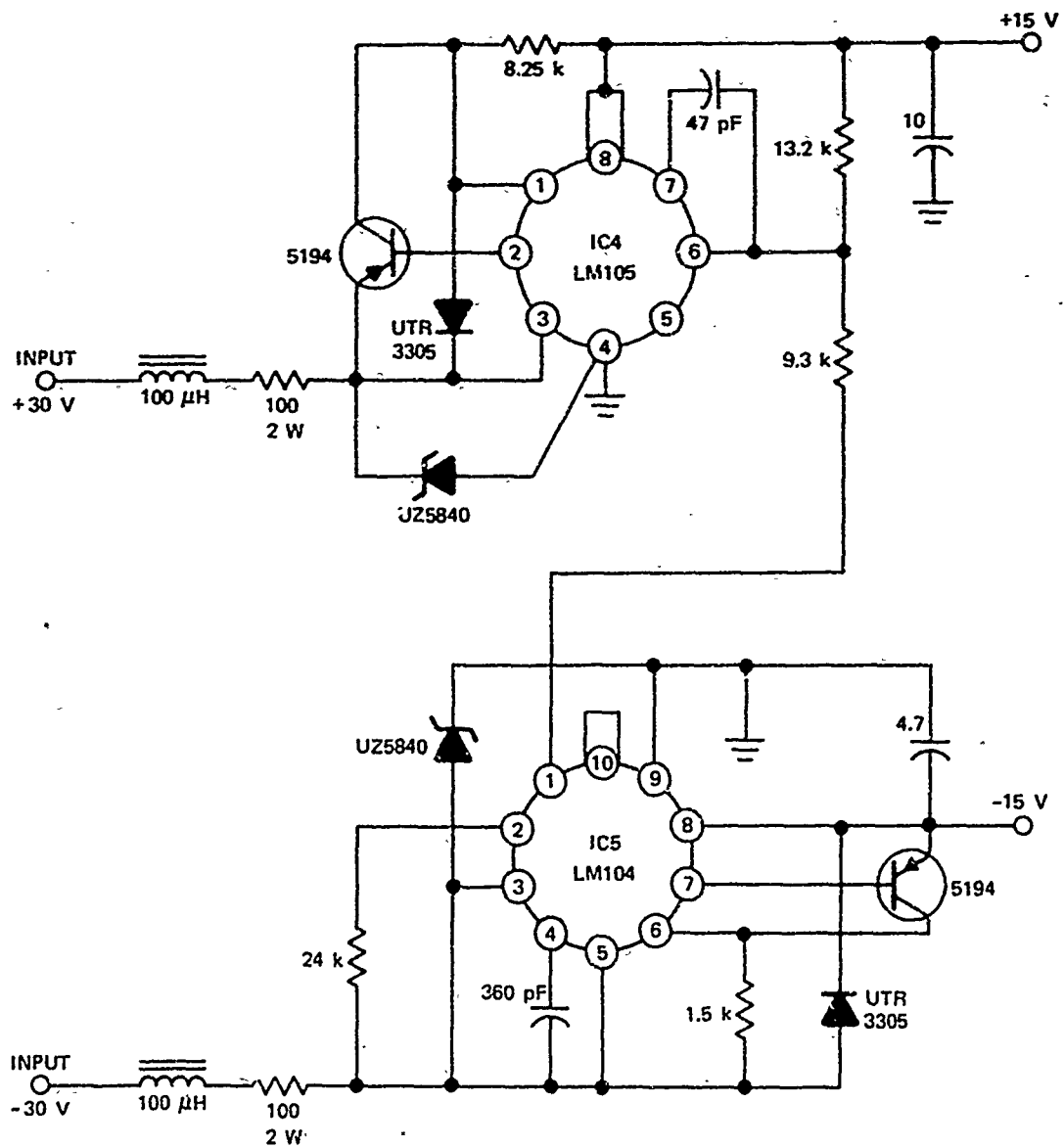


NOTES:

- 1) All capacitors are in μ F unless noted.
- 2) All resistors are $\frac{1}{4}$ W and are in ohms unless noted.
- 3) (p) = 1% res.

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FIGURE 17 ELECTRONIC-VOLTMETER CIRCUIT



NOTES:

- 1) All capacitors are in μF unless noted.
- 2) All resistors are $\frac{1}{4}$ W and are in ohms unless noted.

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FIGURE 18 POWER-SUPPLY REGULATORS

negative voltages for the driver circuits are supplied by the regulators shown in Figures 19 and 20. These are conventional circuits using discrete components throughout. Regulated ± 15 V are used to supply the reference zener currents for improved stability.

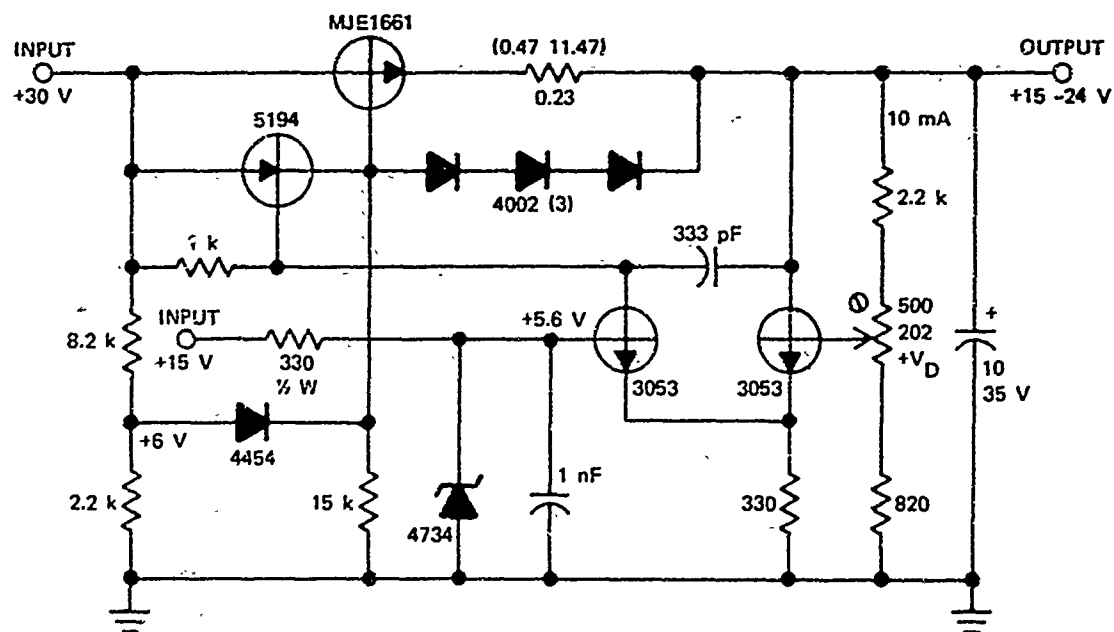
C. Circuit Adjustments

1. Adjustment-Pot Locations

The power-supply and voltmeter adjustment trimpots are located on the circuit board mounted on the chassis inside the unit. The rate-calibration and drive-gate-duration trimpots are located on the gate generator and driver board inside the diecast box mounted on the internal chassis. The pots are each labeled, adjacent to the adjustment screw, to correspond with the designations on the schematic diagram, except the driver supply-voltage adjustment pots which are labeled (+) and (-) instead of $+V_D$ and $-V_D$.

2. Drive-Pulse Adjustments

The amplitude and width of both portions of the HV-switch drive pulse are adjustable and have been set to minimize contact bounce. The fixed bias is not adjustable. The travel times for movable switch contact, closing and opening, are determined by the bipolar pulse amplitudes. For maximum switching speeds the pulse durations must exceed these travel times. The duration of the positive portion of the pulse must exceed the time required to close the switch (6 to 8 ms). The positive amplitude should be great enough to produce rapid closure of the contacts but not so high as to cause excessive contact bounce. The negative pulse amplitude and duration should be set for rapid contact opening, with minimum return bounce. The adjustments are not critical. The amplitudes and widths of the bipolar pulse as shown in Figure 14

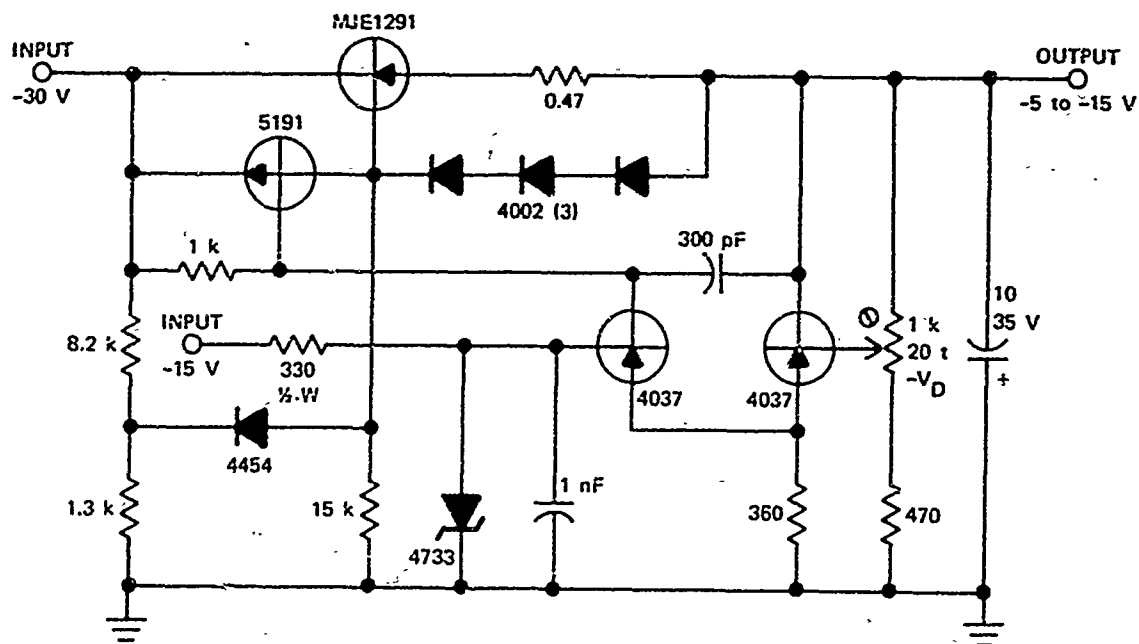


NOTES:

- 1) All capacitors are in μF unless noted.
- 2) All resistors are $\frac{1}{4}$ W and are in ohms unless noted.

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FIGURE 19 POSITIVE-DRIVER REGULATOR



NOTES:

- 1) All capacitors are in μF unless noted.
- 2) All resistors are $\frac{1}{2}$ W and are in ohms unless noted.

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FIGURE 20 NEGATIVE-DRIVER REGULATOR

should be satisfactory. If it becomes necessary to check or readjust the bipolar-pulse characteristics, monitor the coil driving voltage with an oscilloscope and set the positive and negative amplitudes by adjusting the two trimpots labeled (+) and (-). The pulse-width adjustments are R3 and R4. R3 is used for the positive portion of the pulse and R4 for the negative portion. The 50- μ s positive spike on the trailing edge of the negative pulse is normal.

3. Pulse-Rate Calibration

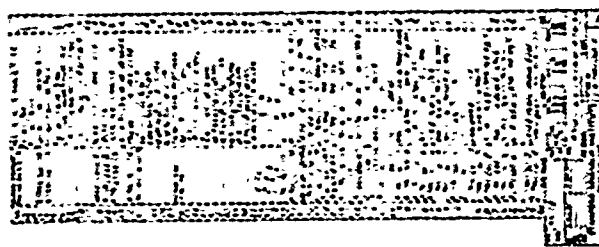
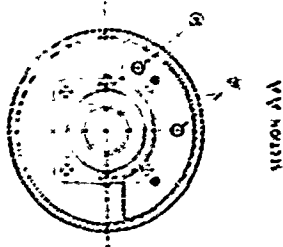
The internal rate-generator control is calibrated as follows:

- (1) Monitor the output drive pulse with an oscilloscope set up to measure the pulse period.
- (2) Set the RATE control to 1 Hz. Adjust R1 for a period of 1 s.
- (3) Set the RATE control to 25 Hz. Adjust R2 for a period of 40 ms.
- (4) Repeat steps 2 and 3 until the periods are correct.

4. Voltmeter Calibration

The HV voltmeter is calibrated as follows:

- (1) Set the voltmeter range switch to 1.5 kV. With the HV-power switch off, adjust the pot labeled Z for a zero reading on the voltmeter.
- (2) Energize the high-voltage power supply and set to 1.5 kV using an accurate voltmeter. Or, alternatively, apply a current of 10- μ A between Pin G and Pin H of J2 (large connector on rear panel).
- (3) Adjust the pot labeled C for a full-scale reading on the voltmeter.



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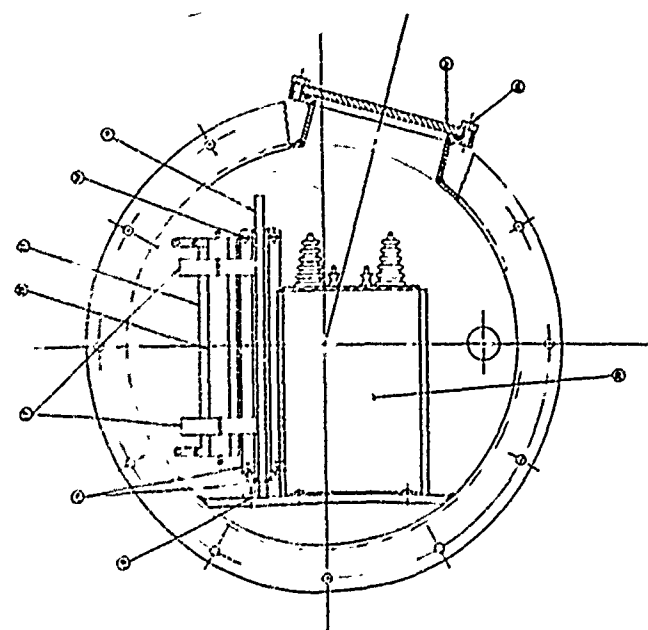
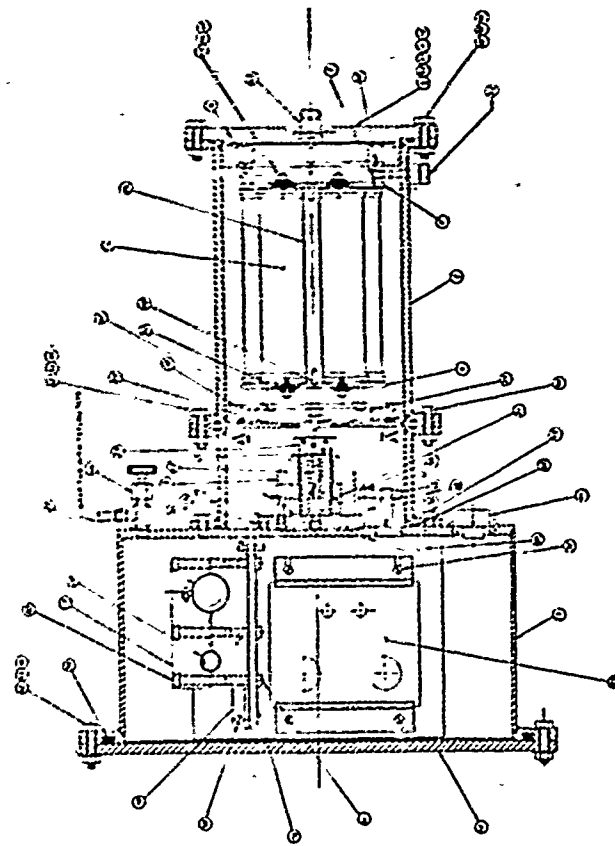


FIGURE 12 DRAWING OF DIRECT-DRIVE-
PULSER ASSEMBLY

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See the following pages
for greater detail.
XXXXXXXXXXXXXXXXXXXXXXXXXXXX

A

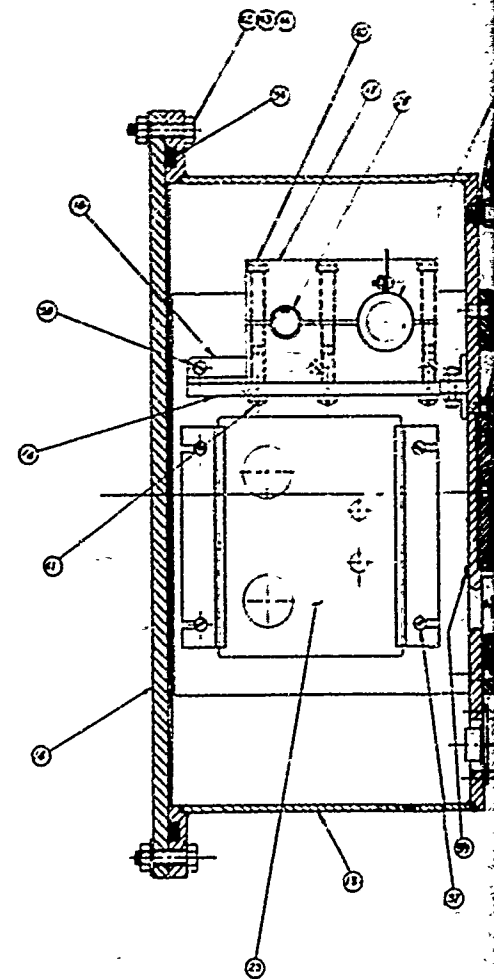
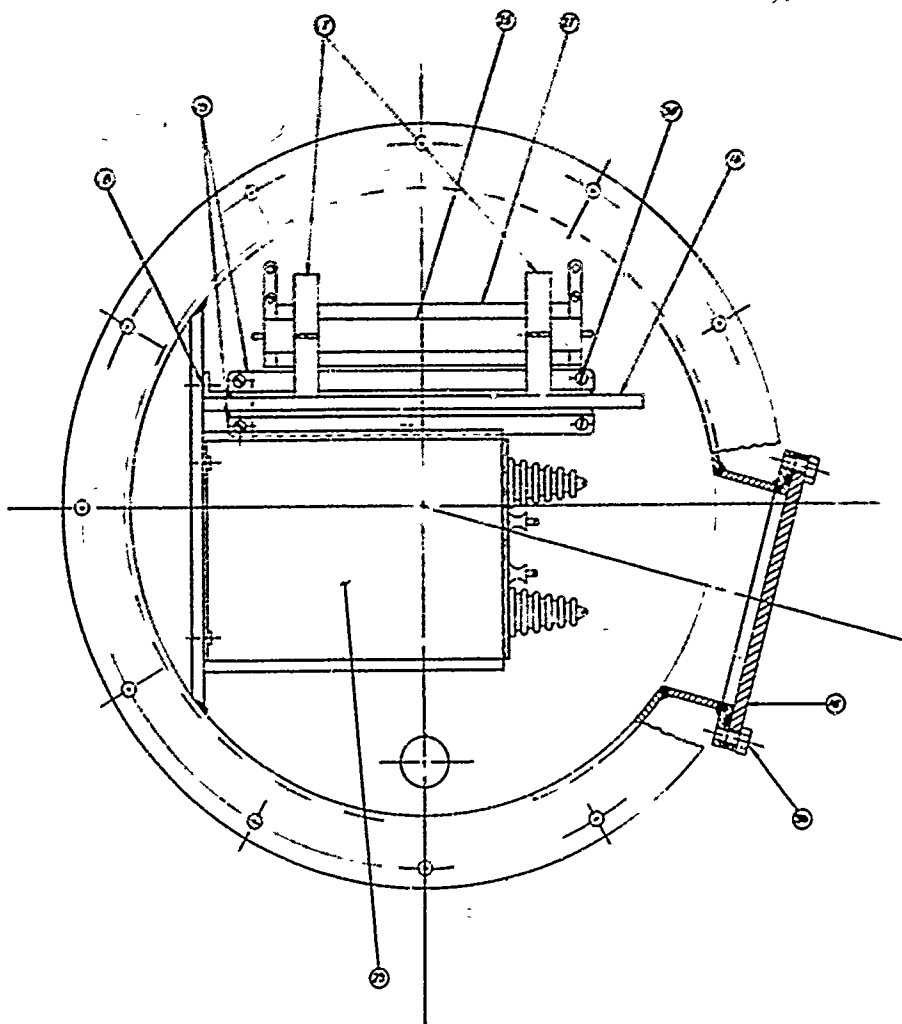
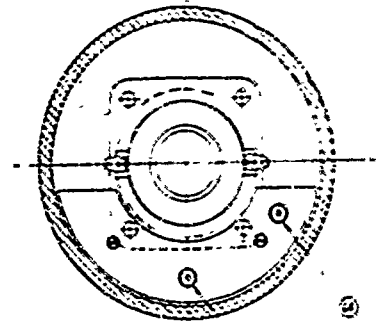
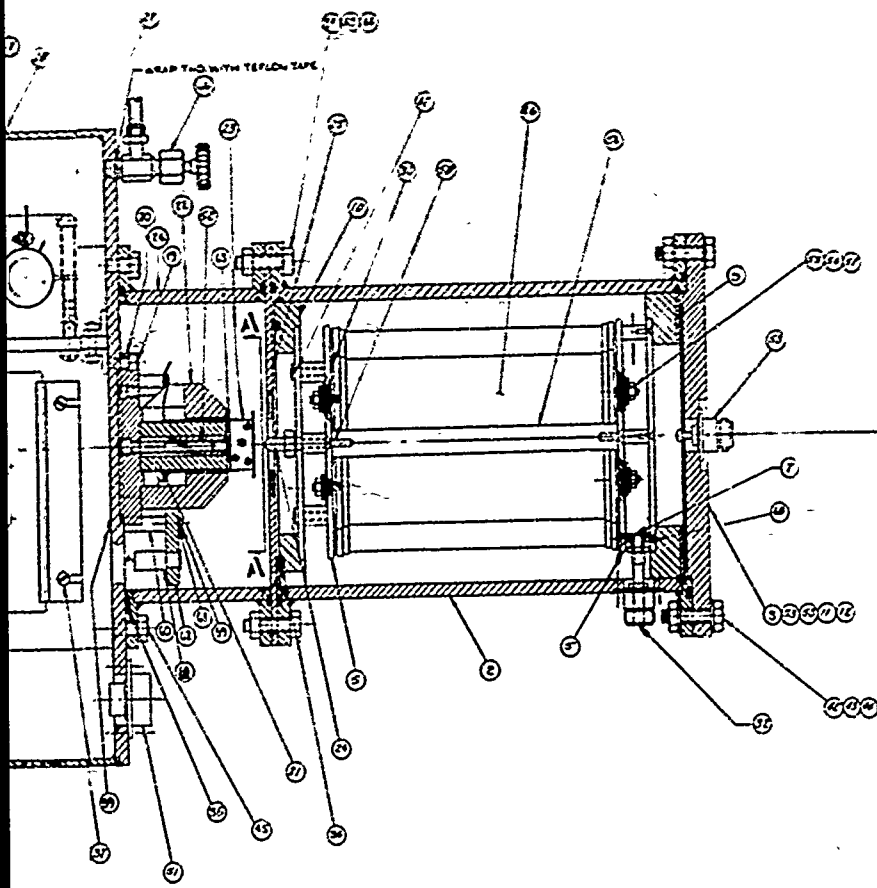


FIGURE 12 DRAWING OF
PULSER ASS

B



SECTION AA



NO.	DESCRIPTION	QTY	UNIT
1	FLANGE	1	
2	FLANGE	1	
3	FLANGE	1	
4	FLANGE	1	
5	FLANGE	1	
6	FLANGE	1	
7	FLANGE	1	
8	FLANGE	1	
9	FLANGE	1	
10	FLANGE	1	
11	FLANGE	1	
12	FLANGE	1	
13	FLANGE	1	
14	FLANGE	1	
15	FLANGE	1	
16	FLANGE	1	
17	FLANGE	1	
18	FLANGE	1	
19	FLANGE	1	
20	FLANGE	1	
21	FLANGE	1	
22	FLANGE	1	
23	FLANGE	1	
24	FLANGE	1	
25	FLANGE	1	
26	FLANGE	1	
27	FLANGE	1	
28	FLANGE	1	
29	FLANGE	1	
30	FLANGE	1	
31	FLANGE	1	
32	FLANGE	1	
33	FLANGE	1	
34	FLANGE	1	
35	FLANGE	1	
36	FLANGE	1	
37	FLANGE	1	

DRAWING OF DIRECT-DRIVE-ULSER ASSEMBLY